

**INTERVIEW WITH BILL LUCAS #3**  
**INTERVIEWED BY STEPHEN WARING AND ANDREW DUNAR**  
**UAH**  
**OCTOBER 27, 1992**

Waring 1: Let's start with some questions on diversification. One thing that several people have told us about, including Dr. Shuhlinger and Charles Lundquist, is that Marshall had an unusual way of dealing with scientists. Marshall, more so than other NASA centers, tended to rely a lot on external academic scientists rather than having a large staff of internal civil servants. Could you talk a little bit about the origins of that practice?

Lucas 2: Yes. I don't know if it started this way or not, but it turned out to be a deliberate policy of the Marshall Space Flight Center to do that. First of all, the mission of Marshall Space Flight Center in the outset was primarily engineering. We did a lot of scientific investigations. I did some myself, but the assignment was primarily one of engineering. Of course engineering is applied science so you have to have a relationship with a scientist in order to carry on advanced engineering work. There were centers of the agency that did have a scientific mission, and they had a lot of in-house scientists. Marshall didn't in the offset and learned I believe that the best approach was to rely upon academic university scientists and scientists from other industries because our primary goal was to develop hardware. By not having a big in-house science [?22] we'll say, the universities with whom we dealt and other organizations didn't feel threatened. It didn't feel it was a competitive situation, and I believe that it improved the relationship between the center and the scientific community. I remembered one day being in a meeting at Headquarters with another center director and we were being interviewed about a certain scientific project in which both of us were involved. The question was asked of me how many scientists we

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had on the staff and I gave the number which was rather small. The other center director knew the question was sort of loaded and so he didn't give a precise number, but he implied it was a little bit larger but not much. Some scientist from his staff in the back of the room raised up and said "Oh we have two hundred" or some number like that. He could have choked this guy. It wasn't a popular thing to have said. I want to give that little story to illustrate that the policy of doing enough in-house work in order to keep ourselves and our contractors honest. We still found it more efficient to deal with university scientists whose total responsibility almost was that. The relationship was improved by the fact that we didn't have a big science group. We had enough people to understand, to communicate well, and to be respected, but not enough to be a threat.

Waring 3: Once again sort of backing into this diversification, could you describe the role of the Research Projects Lab during the '60s? We've heard that it got the nickname of being called the Hobby Shop, or Stuhlinger's Hobby Shop, in the '60s.

Lucas 4: I guess that term was applied and may have been justified to a degree, but I don't believe in the negative connotation that a lot of people would apply to that. Of course you've talked with Lundquist and Stuhlinger both of whom were in that shop so you ought to have a better perspective perhaps than I would have. It was a charge. It didn't have any direct mission that said OK you've got to produce a Saturn IB or you've got to produce this, that, or the other. They had the mission to explore new technologies, to look and seek out those areas of promise to work in. There were people in the Center who were charged with getting this thing invented, getting this designed, getting it built, probably would look over at those people and think well

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they're just doing their hobbies, but hobbies are the sources of eventual applications. I think that was an important thing.

Waring 5: You've talked with us before about program development and the policy of diversification. Did the role of the Research Projects Lab change after Program Development was created?

Lucas 6: Not greatly. I wouldn't want you to have the impression that diversification was the results of the Research Projects Office. That was not the case. It figured into it, but that was not the result. Where the diversification came about was rather specific. You know that the organization had its beginning with the Army in the 50s and then the Marshall Space Flight Center was established officially on July 1, 1960. We've been working for NASA since its formation in '58, but we were established there with a very specific mission of developing the Saturn family of launch vehicles. We had a deadline to do that by the President's announcement of policy. We committed ourselves almost exclusively to that except from a small amount of research that had been authorized along the way. Back then, Dr. Von Braun had the expressed policy of saying that people who were competent to do Research should have about 10% of their time to do independent research irrespective of what else their assignment might be. Of course in the Research Projects Laboratory virtually all of their time was devoted to that. With all of this, this was very small in comparison to the total thrust of the program in the engineering to develop the Saturn family of launch vehicles. We were coming down to near the end of the 60s seeing our goal in sight and realizing "Hey, what's next? When we get to the moon, we will have developed the Saturn V. Then what next?" This was an item that began to bear heavily on the minds of the management of the Center. In the fall of 1968, the Center had a management retreat or hide-away down at Jekyll

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Island, Georgia. We went down there and spent a weekend, and it was on that occasion where the decision was made to establish a development organization. I was asked to organize that, what turned out to be Program Development. At the time the decision was made, we didn't know what it would be called, but its function was to develop new business. When Von Braun asked me on that occasion to take that responsibility, he said "You'll be my Vice President for Sales" in other words the development of the new business. I took over that role with some apprehension because I was happy doing what I was doing and knew that this was a big task to kind of carve out what we would do in the future. I did come back and began organizing the Program Development. It started with myself and my secretary and one other person, Al Flint who is now deceased. He was an administrative type, not an engineer or a scientist. The three of us began developing that organization and working with several other people in the Center. We choose a mission, established a project plan for what we wanted to do, and got that approved by von Braun personally and set out doing that. It was clear that with the progress that had been made in the last twenty years in developing launch vehicles, there would still be other work to do, but that would not be enough to challenge an organization the size of the Marshall Space Flight Center. Diversification seemed to be the reasonable thing to do. I think that's the thing to do for any organization. Management, of course number one when your product, when you have it pretty well developed, you ought to be out looking for other products. That's what we set out to do. The Program Development Organization was designed with that in mind to assure new business for the Center into the 70s and the 80s. That was really the beginning of the diversification. The organization that we were able to pull together there set out with that in mind and in fact developed the beginnings of virtually all the projects that now occupy the Marshall Space Flight Center this day. Aside from history, my belief is that

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it's time for a reinvigoration of that concept because we're coming to a new day in space development. I don't know if that responds sufficiently to what you had in mind or not.

Waring 7: When Marshall began diversifying, it diversified into fields beyond propulsion, but it remained essentially an engineering center. It was getting involved in the engineering of big science projects rather than propulsion.

Lucas 8: That's exactly right, or in addition . . . .

Waring 9: In addition to propulsion projects. This in many ways I think from talking with people, it seems to have changed a little bit of the role of the Space Sciences Lab. The Space Sciences Lab became more central to the engineering mission. Would you say that's a fair characterization?

Lucas 10: What you said is fair, but if I follow what you said, it's not entirely the truth. The facts are that the Space Science Lab was formulated along [?123]. It had been what we called the Space Projects Office at that time with a rather minimal laboratory capability. It first started with Dr. Stuhlinger as a office primarily. He had some other people, but didn't have the capabilities or facilities to do any research. That of course grew, and while it was still called the Space Projects Office, it did gain laboratories, but it was established as one of the principle laboratories of the center just following that decision to broaden and to diversify our operation. The organization of the technical arm of the Center has been called various things that you've undoubtedly discovered, but the basis of it were the so called laboratories which are not just a single laboratory as someone might think but a collection of laboratories with a mission. Following that change at the end of the 60s, the Space Sciences Laboratory was established as one of

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the rest of them. Formally you had x numbers of laboratory and than a project office. This was established as one of the laboratories. It did begin to contribute in that area, and it did then have the capability be called upon to participate more centrally in missions of the Center even in propulsion.

Waring 11: Were there efforts by center managers to strengthen the scientific side of the Center then as a way of helping to get some of these science engineering projects?

Lucas 12: Yes, it was. To strengthen not only the in-house capability to some limited extent. We never wanted to go all out and be a Goddard Space Flight Center which is primarily science, but we wanted to get a little bit more committed than we've had. We recognized that we needed more people in order to establish better relationships with universities. I remember an occasion which is down the road a few years, but it illustrates the point. When we were competing for the assignment of the development of what turned out to be the Hubble Space Telescope, it was called the large Space Telescope initially, we had the administrator of NASA, Dr. Fletcher at the time, down at the Center. Of course we had been trying to make our story, our capabilities in engineering, why we thought we were best equipped in the Agency to do large development. I remember well at a lunch, while we were having lunch and we were talking about it obviously, and he said, "Well now this is not just an engineering project that we're talking about here. You have to have a relationship with scientists. You're serving their needs. For example, Goddard, they have a lot of scientists on board, but they're right in the middle of a lot of universities, John Hopkins, University of Maryland, Georgetown. Who do you have? Who do you have relations with?" "Well" I said, "the University of Alabama." We tried to inflate it as much as we felt justified in doing, but the point was made that to spread out from propulsion where we were the

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experts into serving the interests of scientists where we were not the experts required a better relationship with the experts. That was one of the functions of the Space Sciences Laboratory, to cultivate that community of scientists.

Waring 13: Through the '70s obviously Marshall's size was shrinking.

Lucas 14: Yes.

Waring 15: Were there efforts to protect the size of the Space Science Lab and hire more Ph.D. scientists for exactly the reasons you were talking about?

Lucas 16: Yes. The hiring, let me say, was not very significant during the 70s. The attempt was made. We had built up to a very large engineering organization. We had about 7300 people, civil servants. We had almost an equal number of in-house support contractors at one time, and obviously we didn't have the jobs for that many people. There was a continual decline throughout the 70s. From 1968 until 1978, we hired hardly anyone. We had pretty much, not totally, but to a large extent uncontrolled loss of people. In the government practice of doing some things, you don't just decide "Well we don't need these two fellows anymore, so goodbye." You don't do that. You have to abandon areas of work. Then there are reduction in force procedures which means well if your job happens to be eliminated or abolished, you can go over here and bump someone else with less seniority and you may be working in the area where you have some paper qualifications for but not much recent experience. It might be that you instead of teaching History, you'd be over in the English department. You could do that but not as well as you could do your own thing. We did make the decision. We said well okay we're not going to be any longer a manufacturing organization. When we first

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started the work here in Huntsville in the early 50s, no one really wanted to get into this area. It was a new area and you didn't find industry falling over itself to get involved. I may have told you the story about how we got Chrysler involved before did I not?

Waring 17: Right.

Lucas 18: And other industries. So we had to do the work in-house. Even on the Saturn V program, the first three Saturn V S1C stages were built in the shops at the Marshall Space Flight Center. It was clear at the beginning of the 70s that that wouldn't be anymore. We'd built up a very substantial aerospace industry all across the country, and they were hungry for work. The so called Arsenal concept of doing business that had been our heritage was no longer going to be. We elected to cut down those, we abolished that kind of function.

Dunar 19: Was that a decision that was imposed on Marshall solely or was . . . ?

Lucas 20: Which decision?

Dunar 21: The decision essentially to do away with the Arsenal concept. I know certainly that was a lot of pressure from outside aerospace contractors and so forth, but did Marshall agree with that at a certain point, or did Marshall resist that?

Lucas 12: Marshall resisted that as a matter of policy, but Marshall had to make a choice and therefore it was a management decision part of which was mine. "This is the way it is. You've got this many people and you're going to have this many less. What can I give up that hurts me the least?" Knowing that NASA didn't support the



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philosophy of the Arsenal concept and of course we know why we were with the Army, that was a management decision. It wasn't something that we liked to do. It wasn't something that even today that I think was the best thing to do to a point. There were some things that we shouldn't have been doing. What we found is that we had to have in order to be able to intelligently manage large projects, you have to have some knowledge in that. You can't just pull a kid whose just graduated from engineering school and say "OK got out here and supervise this aerospace industry and the design and building of a rocket." He knows the theory, and he can do that, but he doesn't know the practice. We did a better job of management of hardware contractors when we were able to have the so called "Dirty Hands" approach in-house. To answer your question, it was a local Marshall management decision. Perhaps if we hadn't made it, somebody would have made it for us, but it was made locally as a matter of doing what the question you started out with. We would rather loose the manufacturing capabilities than the Space Sciences Laboratory function because we thought "There's where our future is." That's kind of a rambling way, did that get . . . ?

Waring 13: It's getting at this whole issue. This is obviously a big transition we're trying to understand. Marshall already obviously had some scientists with areas of expertise that would have contacts with the university community in helping getting new projects. Was there an effort to diversify in areas primarily in which Marshall had strengths, get science projects in which there were areas of strength and expertise or was there, could you generalize and say that maybe Marshall was moving into areas in which there were new projects and then developing strength afterwards?

Lucas 14: The latter. Of course it's the chicken and egg sort of thing. If you have a certain strength, you try for projects in that area, but the kinds of new people that we

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brought on were for the most part to strengthen areas where we thought the new business was. We had the vision of what could be done, what we could reasonably expect to do. We didn't expect, as far as I know in my term did we ever expect to be the premiere science organization in the country or the world. That just wasn't in the cards. We did think that we could combine our science capability with our unquestioned engineering capability and do these systems integration and developments of large projects better than anyone else, and that's what we went for. We went for the large projects - the Space Telescope, the High Energy Astronomy Observatory, the AXAF which I hope will finally get done. My wife and I sit next to the Glaskoffs in the symphony. Marty and I laugh about this occasionally. We first brought him on because of his expertise in X-ray astronomy. We were criticized because they said he was too young. We needed to get an older scientists. We laugh about that. I said "Marty I hope you get this thing launched before you get too old!"

Waring 15: What time was he brought on?

Lucas 16: I think it was in the mid to late 70s. I'm not sure about that. He was associated, on the Skylab, and I'm using this as the timing. On the Skylab we had the X-ray telescopes also. One of his major professors was the PI on one of those X-ray telescopes we had on Skylab. We sort of got to Marty through that role. Do you know Marty?

Waring 17: No we haven't talked with him.

Lucas 18: He comes from a very distinguished background. His father and mother were both professors at Harvard, not in science. I don't know if they were History or

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some other Liberal Art and his uncle was the famous scientist who was central to work on the atomic bomb. You may have read about him. Glaskoff illustrates what we tried to do. We tried to bring on those people that we thought where there was a mission that we would get. We didn't have ultimate flexibility so we may not have always done that. Sometimes we employed people because of interest in other people in the Center and because we had faith that they would develop something good. That's the way it is with research. You can't always count on the result. You've got to have a little faith that a good researcher is going to go out and do something good. I think that's what we tried to do. We were able to hire again in 1978, and we brought on a lot of young people. We had the problem then, one of the problems that Marshall has faced in recent years is we had that gap between '68 and '78 where we couldn't hire. The people who, I would say by the time I retired, who were becoming key people in the center ought to have been hired during the period '68 to '78, and they were not. What we called the "bath tub effect" [283] curve comes way down. We emphasized hiring when we were able to again in '78 on the younger end of the spectrum. We had an average age problem. Marshall's average age was, maybe Lewis was a little higher, but we were almost the highest average age in the Agency because we were an old center, and we had come down from a larger size to a lesser size. So we tried to employ what we called "fresh outs" either fresh at the Baccalaureate level or fresh at the Ph.D. or Master's level. Those people are new leaders in the Center.

Waring 18: As Marshall began diversifying into the engineering of these science projects and often getting involved in astronomy payloads. Traditionally in NASA that has been Goddard's area of expertise. Did Goddard resist Marshall's diversification at the Center Director level? Was there any resistance on their part?

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Lucas 19: I'd say there was some!

Waring 20: Could you give us some examples about that sort of thing?

Lucas 21: Well I don't know that I would think of any specific examples except that it was a competitive thing for the High Energy Observatory in the first place. There were people at Goddard, there were people in Headquarters who assumed that that was going to be a failure because what did Marshall know about something like that. There was some resistance to it. What was beneficial to us, we had done a few small things in-house. We were not complete neophytes in this area. We'd done Explorer I with JPL which was a pretty good little accomplishment. We had done some other things, some of the micrometeoroid satellites, Pegasus, three of those. We did LAGEOS. As a matter of fact you've just seen this, LAGEOS II. LAGEOS I was developed in-house at the Marshall Space Flight Center. We had some capabilities there and no one really argued with that. It's just that here are these rednecks down in North Alabama fooling with this high level science here. They just don't know how to communicate with those folks. We ought to be doing that. We did HEAO first, and that turned out to be quite a successful program. It had the stop and go, was interrupted, but eventually turned out to be the most cost effective pound for pound satellite that NASA had ever developed. That helped us in that regard. The biggest problem, biggest confrontation associated was with the Large Space Telescope. That required a few years of haggling back and forth and arguing. It is usually assumed in a situation that it's the Center Director's that are the bad people and everybody else just manages to get the work together. There is some of that, but usually Center Directors, after decisions are made, they forget about that kind of thing, whereas the conflict lingers in the minds of most people who have to work together. That's been my observation. People at the Center Director level usually

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are big enough to fight vigorously for what they want, but when the decision is made, they fight to implement that decision, and I think that was the case. Bob Cooper was the Director of the Goddard Space Flight Center during the early days of the Space Telescope, and he was very vigorous in his seeking that program. Once it was established, then Goddard fell in line and supported it. He and I are close friends. We worked well together. In a program such as the Space Telescope, of course Goddard was not completely out of it. They were responsible for the science factor, and they were involved in all our quarterly meetings and all of our other meetings as well as the scientific community. I had as a consultant throughout the Space Telescope, Lyman Spittser who is a famous astronomer from Princeton. I believe his first program was the Capernicous Satellite Observatory. He was a consultant throughout and attended all of our meetings. We were not operating in a vacuum.

Waring 22: Could you describe the division of labor between Marshall and Goddard? For instance, maybe talking about HEAO here. Goddard resisted Marshall getting the project. Were there efforts by Marshall to try and get control over operations and analysis of the data or was that pretty much set from the beginning that Goddard was going be . . . ?

Lucas 23: That was set from the beginning I believe. There might have been people who were still desirous of that. I think throughout the time people were always desirous of Marshall having a bigger operational role than it had, but I don't believe the top management if the Center was supportive of that concept. I was not because operation goes on forever. It becomes routine, and it ties up an awful lot of people. It's not the thing that excites me. I'd like to move on to something new.

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Waring 24: Not to interrupt there, but would you say that's a difference between an engineering approach to some of these projects or maybe a scientific approach where data analysis would be exciting if Marshall was a science center?

Lucas 25: No I don't believe that would follow because the data are available to everybody. It's like the mailman. Are you excited by what you read in the letter or are you excited by going down to the central railway station and getting the letter. The data that comes down in the stream, everybody gets that. I don't know whether they've finally analyzed all the data from HEAO or not. It was launched in '77, '78, and '79 as I recall, and when I retired, we were still analyzing data from it.

Waring 26: I believe there's still a HEAO newsletter.

Lucas 27: Then they're probably still analyzing data. There are people who just love operations. They like the excitement of being here and seeing the [?391] and all that sort of thing, but it turns out to be a 24 and hour a day job. That says that you've got to have three shifts of people, and they're tied down. The Center, and NASA really for that matter, has never been staffed precisely for the job. The job is driven by the staff. The fact that you've suddenly changed from a development center where everybody works on a shift and a half maybe to where you have a three shift operations, that cuts down what you can do [?401].

Waring 28: Right, I understand that. That's a good way of explaining it. I have one more question and then I'll turn things over to Andy for Shuttle Development.

Marshall always had a great deal of depth in microgravity research and the material sciences. There's a story that's up that I'm just not very clear about. Did Marshall make

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an effort to become Lead Center in NASA or material sciences in the late '70s and early '80s? Did Marshall try to centralize more management over NASA's materials science Research?

Lucas 291: I don't know if that was the case. Undoubtedly somebody wanted to do that because Marshall has always had I believe the best, and probably does today, the most extensive materials science and engineering capabilities in the Agency. As a matter of fact, the materials science and engineering organization from dating back to the time of the Army was almost unique in the whole country. The pioneering of materials engineering as a discipline was done right out there. We were in a predominant role in that regard, but from the science standpoint, we turned out not to be as predominant because the Marshall people had to work on the day-to-day projects. You always had a stress-erosion problem or something else that used up all your talents. We were Lead Center in some respects. I don't believe they ever established a Lead Center for materials research anywhere.

Waring 31: Right.

Lucas 31: There were elements of that where the lead was at various Centers and Marshall has always been prominent in that area. I don't recall a particular consorted effort at any period of history to say "Well, we are going to do it all." I don't think that's the case if that's your question.

Waring 32: The records that survive are very murky about that. How NASA organizes materials sciences is a little confusing.

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Lucas 33: It is, and still is I think. We've just had another reorganization at NASA headquarters. The problem is who controls the funds in headquarters and that has been reorganized from time to time. There's always been a push between the space people and the airplane people, aeronautics people. The aeronautics centers, there are three of those, have that primarily as a mission. The research is primarily their mission. Marshall has always had to compete to some disadvantage with those people because our primary mission is not Research but engineering.

Dunar 34: Let me ask you a last diversification question. This is just something we heard this summer, and we have no documents at all to back it up. We heard that at one point it was a consideration I guess when Marshall was getting into these energy projects of having Marshall transferred from NASA to the Department of Energy. Is that true? Was there ever a discussion of that?

Lucas 35: Well, yes. There was some discussions of that. When we started in this Program Development organization that I organized and headed until I became the Deputy Director, we pursued a lot of different things. You've probably Undoubtedly read about the automated coal mining that we worked in and coal gasification. We did quite a bit of energy at that time. We had this solar house out there that no longer exists. We were following some of the trends of the time to try and take a role in that regard. Because of that, Jack Smith, the astronaut Jack Smith, Harrison Smith, was an associate administrator in Headquarters at that time. He was very much interested in energy, particularly solar energy coming from New Mexico or Arizona, which is it? Anyway, it would be the same thing both cases. That's what happens when you get older! Anyway, he was interested in that, and we did have some discussion, never at a very high level, and I would not characterize them as having being very serious. We did



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some work for the Department of Energy and there were some who though maybe we ought to become an element of the Department of Energy, but that was never pursued to any significant degree.

Dunar 36: Going back on early shuttle development, . . . .

Lucas 37: Excuse me, there were a lot of things, you know those things I'm sure we did in diversification.

Dunar 38: Yes.

Lucas 39: That's a matter of record I suppose.

Dunar 40: Yes. One thing in the early configuration plans was the discussion of using Saturn engines for propulsion for the Shuttle. Why was that not pursued?

Lucas 41: They really didn't fit when it comes right down to it. There were two fine engines developed for the Saturn program. The F-1 engine which is a very large engine, a million and a half pound thrust, kerosene type liquid oxygen engine. The other was the J-2. The kerosene engine was too large and too heavy, and it was really a first stage engine. In rocketry, when you go into a multistage rocket, and I don't want to confuse you with these numbers but just [?504]. There's a term called "specific impulse." Are you familiar with that? It really refers to the efficiency with which fuel is burned, the amount of energy you can get per unit of fuel. You know from the rocket equations that what we need from the first stage is a high density impulse. Kerosene is a better first stage fuel than liquid hydrogen for example. But when you get into [?513]

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evaporations, that is not the case, and hydrogen is far better because you can get a higher specific impulse out of it. I've forgotten exactly what the specific impulse of the F-1 engine was but it was less than 300 we'll say. The specific impulse of the shuttle engine is 454. That's a big jump, and the specific impulse of the J-2 was about 320. The engine that we have for the Shuttle, although they're complicated and cause a lot of problems, are probably the highest energy efficient engines that have ever been developed. Those other engines didn't fit the concept of having what we might call a stage and a half orbit. Does that answer your question?

Dunar 42: Yes. Another thing too during the configuration period, how influential were the Bellcom studies in planning configuration?

Lucas 43: Of the Shuttle?

Dunar 44: Yes.

Lucas 45: Well, Bellcom was far more prominent in the Saturn program than it was in the Shuttle program. I don't know that they're any more or less influential than other considerations. The Shuttle was designed to do the joint mission between the air force and NASA. As a result, it wasn't [?541] anybody. The size of the Shuttle, the cargo bay, the performance of the Shuttle in orbit were driven largely by Air Force requirements.

Dunar 46: One of the things we're tracing here and trying to sort out is the degree to which some of this was an effort by Headquarters to take away some of the Center autonomy in the period at the end of Apollo. That may not be an accurate observation, but it seems to be to us one of the things going on at that period. We're wondering if

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maybe not doing it in-house, could that reflect a Headquarters' desire or could it reflect Air Force influence?

Lucas 47: You've got me stumped here a little bit. I don't remember Bellcom as having a significant impact on the Shuttle. Bellcom did have a systems integration impact on the Saturn V and as long as the so called Boeing tie contract we had which was a Headquarters initiative to pull these two things together, there probably was a desire to do a similar thing to the Shuttle. It might have been a good idea to do that to the Shuttle, I don't know, but there was not that capability nor that money to do it in the Shuttle program. In the Saturn program, we had plenty of money, and we've never had enough money in the Shuttle. So these, Bellcom's and Boeing tie contracts, are very expensive and they don't come for free. I don't recall Bellcom having made any very significant impact on the configuration of the Shuttle. The configuration of the Shuttle was hammered out between the propulsion capabilities that we visualized and between the requirements for NASA and for the Air Force and the expression that this was going to be the launch vehicle that would carry everything from the Scout payload to the biggest one, which was unfortunate, that it was done. So it wasn't [?587].

Dunar 48: The debate of course that was going on at that time whether or not NASA's next big project should be the Space Station or the Space Shuttle. How did Marshall management feel about that?

Lucas 49: Well, it was Marshall management, Program Development organization which I headed that proposed the long-range plan. I guess you've seen that so-called Miller plan, we did that for George Miller, that proposed a Space Transportation System, a Shuttle and the Space Station simultaneously so we needed both of those

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things, but we couldn't have them both because of economic reasons. When it came down to it, Marshall and I guess everybody else, would have liked to have developed the Space Transportation System and the Space Station simultaneously, but we couldn't do that. If one has to make a decision, do you develop the Space Station or do you develop the so-called low cost Space Transportation System? The decision has to be rather obvious. You have to have the transportation system. If you have a house out on the lake somewhere, you've got to have a way to get to it. That's the same way with the Space Station. The criticism, self-criticism as well as external criticism, of NASA's Apollo program could not have been with the success of the mission, infinitely successful. The problem stated at the time was they'd cost too much money to launch. Two-hundred million dollars a launch for a Saturn V. So we're going to be able to carry payloads up for three hundred dollars a pound. You know how near we've gotten to that don't you? We haven't gotten there and we won't ever get there. [627 turn tape over]

Dunar 50: . . . with the Shuttle versus Station to be made at that time. Was there a decision at Headquarters as that went into the decision to make JSC the lead center, was there a trade off there where Marshall was given some promise of being Lead Center on Station then?

Lucas 51: I don't think so. Not to me, and I was the Center Director. You could infer that "OK, they got that one so we'll get the next one." That was kind of the hope that we had, and Marshall did turn out to be predominant in the Space Station.

Dunar 52: When the decision came down to make JSC Lead Center, there were two documents and I'm trying to remember who, I think one was [?632] if I'm not mistaken

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but it may have been Dale Myers. There was an early kind of position paper that discussed that as a possibility. [?634] when it became policy that was not included, but it did look like that was probably discussed. I'm inferring that.

Lucas 53: When the assignment was discussed?

Dunar 54: Yes.

Lucas 55: Oh yes, that was discussed many times in Management Councils and that kind of thing.

Dunar 56: But it never became an agreement then? I'm talking now about the idea that Marshall would assume Lead Center responsibility on the Station.

Lucas 57: I'm sorry. I answered you incorrectly. When I was saying it was discussed, it was discussed a lot as to who was to be Lead Center on the Shuttle. That was discussed a lot. There may have been some inferences that Marshall would then get a lead role on Station, but I don't recall that there was a document . . . .

Dunar 58: This was not a formal, it was I think a memo that discussed positions or options and possibilities. It wasn't anything that nailed anything down solid.

Lucas 59: That was probably to soften up our objections to Houston being selected as Lead Center on the Shuttle.

Dunar 60: For a time it appeared that Marshall would be Lead Center on Shuttle.

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Lucas 61: Marshall started back in '69 -'70 with the earliest study that I'm aware of in NASA on the Shuttle was done by the Marshall Space Flight Center in Program Development. We had at one time this catamaran shuttle that was General Dynamics. Marshall took a lead in developing and identifying the program itself. JSC came from a heritage of airplanes, and I think that as much as anything else resulted in their having been selected. They came out of the Langley Research Center which is primarily aeronautical, well goes back to 1915 or thereabouts. I think that had a lot to do with it, because Marshall, although we were well-recognized as big structures people and propulsion people, we were not aeronautical people. We had a few people from Langley too and a small wind tunnel, but you couldn't say that we were experts in aeronautics. I think that as much as anything as far as the technical considerations are concerned directed that assignment to Houston. Technical considerations were not all of it. There were political considerations and that was probably the most important.

Dunar 62: You mentioned the Miller plan. I've seen that and had not realized that it originated in the Program Development.

Lucas 63: Yes it did.

Dunar 64: Could you describe how that came about and maybe a bit about the relationship too between George Miller and Marshall management at that time?

Lucas 65: George Miller had a very good relationship with Marshall. He gave us a hard time like any manager does, but as far as Marshall is concerned, I think George Miller was probably the best, most positively oriented towards Marshall of any of the

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associate administrator we've had. This plan was worked out while he was the Associated Administrator and it was worked out. I may still have if you haven't seen this plan, it was a program book worked out, and we still have those view graphs around. As a matter of fact, I used some of them in some kind of a speech that I made two or three years ago. I may still have it in my drawer. It shows how this plan was laid out. Do you want me to take a minute and see if I can see it?

Dunar 66: If you don't mind.

Lucas 67: No I don't mind doing it. [tape off 670]

Waring 68: Did Miller make it a practice of using Marshall as a sort of planning staff? He seems to have done this for Skylab too.

Lucas 69: Well that's because we had a planning staff.

Waring 70: There just wasn't personnel available at Headquarters to do that?

Lucas 71: No. He didn't have nearly the confidence in his Headquarters staff as he had in the Marshall staff, and they were not the same.

Waring 72: The Marshall people had more hardware, hands-on experience?

Lucas 73: More engineering experience. [?681] I'm looking for. That one starts in 1980 there.

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Dunar 74: [?682]

Lucas 75: No, I mean the time frame. Let me see that one just a moment. This one didn't have a time frame on it, but it shows where the Saturn V program goes down to. Here is the Apollo program. Here's the Space Station coming along, and here's the development of additional launch vehicles out here. That's not as good of one as I had, but I can't put my hand on the other one right now. That plan probably still exists. You can talk to some people out at the Program Development and get that material that we developed. I just thought I might have one here that I'd gotten from them. This is the kind of thing that was done as planned to be presented to Congress from year to year [?693] Marshall Space Flight Center. I may still have something, but it's probably not worth the time.

Dunar 76: You commented before about center rivalry, and we have talked to you about that before, but I wonder if you could comment on the nature of center rivalry between Marshall and Johnson first during the configuration period of the Shuttle?

Lucas 77: What aspect of it? The technical positions of the various people or you mean . . . ?

Dunar 78: I guess the overriding thing at that point was the role that the configuration had on who would be the lead center since that was developing at the same time.

Lucas 79: As I recall it, Marshall's concern about the configuration primarily was in regard to the propulsion capability that we had. We were concerned with the configuration of the engines that we put on the aft end of the Shuttle and the weight of



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the Shuttle. One of the things that concerned us was that during the process of the development, the shuttle configuration, I mean the orbiter configuration which was primarily a JSC function, appeared to be growing in weight. We had seen that pattern before in the Apollo spacecraft, and fortunately we had enough extra power to put it up there. I think the Apollo spacecraft initially was supposed to have weighted about 78,000 pounds, and we sent more than a 100,000s of spacecraft to the moon. I remember having made this comment myself and said, "Fellows, you've always counted on us being able to upgrade this engines, but this engine has been upgraded before we start. That's all there is. You can not expect to get more performance out of this engine than we're now offering." This is a big concern that we had.

Dunar 80: In fact, that discussion of weight continued throughout development?

Lucas 81: It did, and we finally had to eat some of it, not in the engine because it's right. Well we had operated 109%. That's more than we thought we had to do, and we had to take a lot of weight out of our tank to count for that. That was the kind of thing that went on. Of course there has always been a rivalry between Johnson and Marshall, both of them strong engineering organizations, two strongest engineering organizations in the agency. I believe that it has been exaggerated and overstated. It makes a better story when you're talking about all the knock down drag out rivalries. I don't think it was ever as bad as it has been conveyed. Much of it that has been interpreted as fighting between them is natural to an engineering development when you present the points for and against and decide which is the better.

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Dunar 82: One of the things that had the potential at least of creating rivalry is the fact that many people at Marshall were reporting both to you and Robert Thompson in the Program Office for the Shuttle. How did you work out that relationship?

Lucas 83: You mean . . . I see what . . .

Dunar 84: In effect they had two bosses.

Lucas 85: That was great awkwardness I guess was the way you'd describe that. That kind of thing can work and did work. It might have been better to have done it otherwise, but that's what you call a matrix organization. We have the same thing with them, the Marshall Space Flight Center. For example, we had a Project Office, and still do have a Project Office in the Marshall Space Flight Center. Then we have people here in the laboratories and the Chief Engineer belong administratively to the Director of Science and Engineering, but they respond to that person over there for the project direction. That's the same way it was here that Robert Thompson was the level two so to speak, but that's no different than if he had been in Washington. We had a level two in Washington during the Saturn Program. That's by definition what it is. Whether he's in Houston or in Washington really made no difference except for that undercurrent of rivalry between the two centers I suppose. It's a peer situation whether you want to be managed by a peer or whether you want to be managed by someone who has a superior position. As far as the management concept, there's nothing wrong with it. I think it would be natural to assume particularly when the going gets rough and you need more funds and you say, "Well here's the person who is beholden to the Center Director at Johnson, and if it comes down to a decision of who gets the money, is it going to be Marshall or Johnson?" You would jump to the conclusion that it would be Johnson. It's

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probably not right. You have to assume that the man is one of integrity, and he's going to make the decision as he calls them. I'm just talking about the appearance though feeds that kind of talk. That's why it would have been better to have had the Program Manager in Headquarters for example. He still would have come from one of the Centers, and in most cases they did. It's just the appearance. I don't think the actuality is much different, it's just the appearance of it.

Dunar 86: They kept control of the money in Washington anyway. Is that right?

Lucas 87: Yes, that's right, which is another . . . theoretically they kept control of the money in Washington, but if a man is going to run a program, he has to have the money.

Dunar 88: He has to be able to make plans with it . . . .

Lucas 89: That's why it was kind of a bastard program. If you're going to be a Project Manager, you've got to control the resources. That's what's referred to as the golden rule: he who controls the gold rules. So the Project Manager should of had the money. I'm sure he would say that.

Dunar 90: I know. He did.

Lucas 91: Objectively, I would say that. Headquarters was trying to control the money to allay these concerns about this rivalry, and what I believe could have been an exaggerated rivalry between Johnson and Marshall. The reason it was put down there is that a Project Manager, irrespective of how good he is personally, can not do the job alone. He's got to have a staff of project managers, and there was nobody at

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Headquarters that could do that. I would say nobody is an overstatement, but they didn't have a core of people from whom one could select the project office. It's so difficult to get people to go to Washington because to transfer from a Center to Washington, immediately resulted in a substantial pay cut, what's equivalent to a substantial pay cut. You didn't get any more money, but the cost of living was so much higher, and the place you have to live is not nearly as attractive as Clear Lake or Huntsville. It was difficult to get your best people to go up there. If you pushed them to go, some of them would, but most would say "If that's my choice, I'll go somewhere else."

Dunar 92: On a day to day level of operations, if for example there were a technical problem that arose on one of the Shuttle components, how would you and Robert Thompson divide up responsibility for that in terms of whose responsibility it would be, or did that really happen?

Lucas 93: In Robert Thompson's role, he was responsible for the total Shuttle, and I wasn't responsible. I had a Project Manager. I didn't relate with Bob Thompson officially at all.

Dunar 94: That's what I was wondering.

Lucas 95: My Project Manager would relate to Bob Thompson. We had this level I, II, and III. Level I is the administrative use at that level. Apollo was that way. Level II is the Program Office at Washington, and Level III is the Center. Or, level I is the whole stack and Level II is the whole stack, but Level III is the various elements of the stack.

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My manager was responsible for the Level III, according to Bob Thompson, for the project. I didn't report to Bob Thompson, nor he to me.

Dunar 96: You got greatly involved with the technical problems that did develop during this time. Did JSC have concerns about that, about the degree to which you were involved in the day-to-day . . . ?

Lucas 97: I'm not aware that they were. I would think they would appreciate it.

Dunar 98: Sure. I'm just trying to see how this relationship [?802].

Lucas 99: This has been the Marshall Center practice for the management to get involved in the technical aspect of it. I conducted monthly reviews of the program where my Program Manager would report to me and my staff on the progress of the project. The Johnson Center would be invited, and usually did, send representatives to that meeting, so they were aware first hand of what was going on. I don't believe during the Shuttle program, there was any concern, certainly not on the part of Bob Thompson about that. I think, on the other hand, he would be pleased that the whole resources of the Center, if necessary, were being brought to bear on that project.

Waring 100: Do you think Houston operated essentially the same way where the relationship between their Level II office and JSC Center Director was essentially similar to Marshall's relationship with its Level III offices, program reviews, and then center-wide reviews?

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Lucas 101: In some fashion, I don't know if they did what we did exactly or not. They had a Level III like we had a Level III.

Waring 102: Right, for the orbiter.

Lucas 103: Sometime it was said, they had the criticism that they were letting the Level II man, who happened to be a Houston man, would favor Marshall over their Level IIIs. That's all kinds of things that are it seems to me are peculiar to nothing except human relations. They had a Level III that would be on the level with our Level III and then they had a level II who happens to be located at the Johnson Space Center. Sometimes these interfaces probably got blurred, but that would be the same case even with Marshall.

Dunar 104: You commented on George Miller's relationship with Marshall. Could you comment on the relationship between Dale Myers and Marshall?

Lucas 105: Dale Myers was with the beginning of the shuttle?

Dunar 106: Yes.

Lucas 107: I think he had an adequate respect for Marshall. I don't that we had any real difficulties with Dale that would warrant discussion. I'm sure that without any question, the warmth of the relationship between Marshall and George Miller was much greater than Dale Myers. Here again, a lot of this is probably just perception because Dale came out of what we'd say the Houston mold so to speak. I don't think he exercised that to any significant degree when he got to Headquarters, but he had been

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at Rockwell International as the program manager on the Apollo capsule or in that area, not the program manager but in that role as a contractor to Johnson Space Center. Then when he goes up to Washington, it's almost human nature [to expect] "Well, he'd going to favor those people." I don't know that he did. I do know that relationships, although not bad with Dale, but were not as warm between the Center as with George Miller.

Dunar 108: There were some rather terse notes from Dale Myers to Eberhard Rees over the issue of in-house capability at Marshall in effect telling Rees to be sure to curtail any outside activity during this period of configuration on the Shuttle. Was it part of Marshall's goal to try to maintain, I know you can discuss this a little bit later, but did Marshall, under Eberhard Rees, attempt to try to maintain as much as possible of the in-house capability and did that cause a reaction . . . ?

Lucas 109: It probably did, and Eberhard did come out of that mold. Eberhard Rees' background is in that very area and Eberhard Rees saw the problem the problems that could be solved by knowing that and Eberhard Rees was called upon to help Houston out of a problem when they had the fire in 1967 that burned the astronauts. He actually went out to the contractor and not only that, but Marshall supplied a lot of money. A lot of our funds, we transferred to Houston to solve their problem with. I don't know that, any manager whether it's Eberhard Rees or Bill Lucas or whomever, if he's got a resource he believes is necessary for doing the best job, he'd going to try and protect that. Dale was faced, I'm sure, with confronting the Administrator and Congress with an idea of total resources, and he wanted to cut that down. I suppose that was the reason for it. I'd have to review that documentation maybe to refresh myself a little bit. Clearly, Headquarters applied the pressure to Marshall to come down.

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Dunar 110: That makes sense.

Lucas 111: And we thought unfairly, and still think unfairly, but that's the way it always appeared to the person who comes out on the short end of the stick.

Dunar 112: Why did Marshall ascent to the decision to use solid rocket boosters?

Lucas 113: In the Shuttle?

Dunar 114: Yes.

Lucas 115: Well, it seemed to be that if you're going to have a space and a half to orbit, it was the cruder thing to do. You couldn't get that much thrust from a liquid engine with a single stage so to speak.

Dunar 116: So, it was on a technological basis?

Lucas 117: Marshall would have preferred to have had a pure two stage rocket where we would have had a booster stage. We even talked about the fly-back booster stage. That wasn't to be, and it had some disadvantages that you can see because the stack is a lot higher. The height of the Saturn V was about 365 feet, and the Shuttle is much less than that. I think maybe 265 or something like that. There are certain disadvantages to flying a rocket like that through wind sheers and other things in orbit. I don't think it was a question of why did Marshall accepted it. I don't know that Marshall had a [choice]. It came down to the point where the decision was made to do it another way,



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so Marshall had to do it that way. Marshall, as I said, wanted first of all the fly-back booster or a liquid booster that would be recovered in the same fashion that the solid is, but the others prevailed.

Dunar 118: Once the decision was made not to go with the fly-back booster, that in effect dictated the decision to go with solids. Is that right?

Lucas 119: I don't know that that's right either. That is part of the story, but you still didn't have to have a fly-back booster. You could have had an expandable booster, but I think it would be far more costly than the solid rocket. The rocket engines themselves are very expensive. I think a shuttle main engine costs about \$35 million each when I retired, and Undoubtedly they cost more now. It would have had required a development if you had a liquid rocket and not a fly-back, if you'd had a liquid rocket then you'd have this engine on the tail and probably the tank part was not worth recovering so you'd have to have a separation device and then you'd have to have some kind of clam shell to case the engines so they wouldn't get wet. The corrosion would have been much worse on the liquid engine. They would have to have been torn down completely and probably rebuilt. I think, and it may be true, that when the decision was made not to have a fly-back booster, then you still could of had a recoverable booster, but that became less and less practical as compared to the promises of the solid rocket ones. We did, at one time, dunk an engine, I've forgotten which it engine it was, but it was one of the rocket engines we'd dropped in the ocean, pulled it out and fired it to show that it could be done. We also pulled out one and disassembled it to see how much corrosion had taken place. There was some after a period of time. The fly-back booster, there was a lot of consideration of safety in that regard. You had to have a

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crew to fly that booster back. If you had a malfunction, how would you save the crew. It would have been very difficult to have done. Of course the smart thing that they've done if you have a fly-booster was to fly it back automatically, but that would be another added cost. The parent cost driver was the thing. There were several proposals, we had three or four proposals and when the proposals were evaluated, the best proposal from the stand point of cost included the solid. There were still people who proposed in the competition to have a liquid booster.

Waring 120: Were there center differences on the propulsion, significant Center differences between Marshall and Johnson?

Lucas 121: In what respect?

Waring 122: In the proposed configuration for . . . ?

Lucas 123: I think Marshall, when the competition was made, it didn't become a Marshall/Houston matter. There was a Source Election Board, an SEB, which was made up of people from Headquarters, people from Marshall, and people from Johnson. It wasn't a Center vs. Center thing, but it was that Source Election Board and the Administrator that made the ultimate decision.

Waring 124: And it was cost primarily that would go . . . ?

Lucas 125: That's the way I recall it. It was cost. It was judged that any of the configuration could have done the job, but the job was the big driver, cost and saving.

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Waring 126: In talking about cost, were they primarily thinking about development costs or operational costs? Which do you think was the primary factor?

Lucas 127: I know the factor was in a cost, in doing costing of a vehicle like that, development cost is one thing, and then cost out to a certain number, so you don't ever cost it on the basis of first flight. It's a learning curve that you go through. You usually factor in the learning curve, and I've forgotten the number, but that was factored in. That was development plus flying x numbers, whatever that number turned out to be.

Dunar 128: In 1973 there was a discussion of the requirement for thrust termination which was the one that ended up, apparently from what I can see in the documents, it looks like Marshall opposed the elimination of that requirement.

Lucas 129: Yes I remember that. I was in that meeting and I remembered that, one meeting where it was finally decided. Marshall did oppose that because we'd always been accustomed to being able to cut off liquid rocket. You can cut it off and save it from tearing itself up and creating a more hazardous explosion. You can have a problem that damages the engine but you can contain it to that engine. Marshall's history has been that way. I remember that meeting that we discuss about that, and we argued, at that time, "Well look, if you're not going to make the decision now, at least put in the ports, or places that you can put the ports in so that you leaving the option of doing it at a latter time. That was denied also because it would have weighed more. The only way you can terminate it to let the fire go out both ends. You're getting thrust out the back. You can't stop it from burning. It's just like [973] going to burn. What you do is blow the head of it off so the other half of it comes out one way and it gets a met-zero thrust. That's the way you terminate it. Instead of blowing the head off,

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you establish big ports so in effect you've got a nozzle that points the other way. If you want to terminate you blow that and fire goes out the other end and neutralizes the fire coming out the thrusting end. It was a weight matter.

Dunar 130: It was weight more than cost?

Lucas 131: Yes, it was weight primarily. I don't think cost, cost might have entered it. Costs always enters to a degree.

Dunar 132: Sure.

Lucas 133: The principle reason that I recall that decision was made was a matter of weight.

Dunar 134: If that had been maintained, would that have been sufficient do you think for the prevention of the Challenger accident?

Lucas 135: No it would not have. We didn't know we had a problem until it was too late.

Dunar 136: Could you comment on your prospective of the strengths and weaknesses of each of the major prime contractors on Marshall's major components like Martin Marietta and the tank, and so forth?

Lucas 137: What do you mean strengths?

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Dunar 138: Their strengths in terms of the management strengths that they had at the contractor; the abilities that they had that won then the contract they carried through on; the areas in which you were impressed with their performance and areas in which they fell short.

Lucas 139: You mean after they got the contract?

Dunar 140: Yes.

Lucas 141: I thought you were talking about getting the contract. That would be a matter of record.

Dunar 142: I'm speaking more in terms after they had the contract and during the time  
....

Lucas 143: Martin was one of our premiere contractors. There's no question about that. They did an excellent job on the tank. They started off a little slow and here again the old Arsenal concept came into bear. We did not have the manufacturing capability any longer but we did bring back from retirement on of the people who had been instrumental in doing the welding on the Saturn program and sent him down to Martin for about six months to help them get started in that regard. Martin did a good job in laying out the plant, developing the welding techniques and the insulation techniques. Martin just did a fine job on the tank.

Dunar 144: The welding techniques, a lot of them were developed at Marshall. Is that right?

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Lucas 145: Yes. That's why we sent the man down there. The variable polarity and [?013] welding, those techniques were developed there and are still working on those techniques at Marshall. As far as I knew, there was a very good interface between our people at Marshall and their counterparts at Martin. That produced a good program.

Dunar 146: How about Rocketdyne?

Lucas 147: I think they developed an extraordinary engine. It turned out to be a very complicated engine and one that was very sensitive to minor differences. They did a good job as they've done throughout the years that they've worked with the Marshall Space Flight Center. One of the big problems of the engine was the controller and Honeywell developed that controller. I didn't characterize Honeywell as being a very good company to work with. They eventually did develop a good controller, but in the early days when we were having problems, they were not as responsive in my experience as we were accustomed to contractors being.

Dunar 148: In that sort of a situation since Honeywell was a subcontractor to Rocketdyne, did Rocketdyne put pressure on them or did it come from Rocketdyne and Marshall?

Lucas 149: Both. It came from Rocketdyne and should have all together come from Rocketdyne, but sufficient progress was not being made so some of it came from Marshall also. They were not really sufficiently responsive in my opinion to have worked out some of the problems.

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Dunar 150: There was a consideration for a time of developing a back-up wasn't there?

Lucas 151: That's right.

Dunar 152: Was it because Honeywell finally did respond that they chose not to do that?

Lucas 153: When it got to where it would work, you don't spend money if you don't need to even though you could Undoubtedly develop a better controller today. That's an expensive proposition and when you're constrained for money in particular you don't fix something that's working.

Dunar 154: There was concern early in the development of the main engine about Rocketdyne's management and failure to keep pace with their schedule. It appears that after the first year or year and a half of the contract, those problems were worked out. Is that an accurate perception?

Lucas 155: I'm not sure. The problem of Rocketdyne in the early days has its roots in a contracting manner. The competition for the Space Shuttle Main Engine was between Rocketdyne and Pratt and Whitney. They were very close, very very close. The decision was made of course for Rocketdyne. Then Pratt & Whitney immediately entered a protest on the decision and it took a year or more to adjudicate that request. It didn't change anything, but what it amounted to was that for that year, if that's the right number I think it was a year or maybe more, for that period of time, there was a blackout between Marshall and Rocketdyne. We couldn't deal with our contractor, yet the contractor had to proceed because of the schedule to develop this engine. That was

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a weird kind of thing. This also illustrates another problem with the Shuttle, and that is we didn't leave enough time to develop that engine in the first place and the thrust of the engine changed during the course of that time. There were some changes in the specifications and the fact that Marshall couldn't deal with its contractor I believe could be attributed to some of the problems we encountered down the road. In addition to the fact that it's just a very complicated engine. That high speed turbine that goes from zero to 35,000 RPMs in milliseconds tells you something. That's really taking off. It was a very demanding job. There were some of the things about the engine that were not understood until well into the development. Some of the fluid dynamics where we used wind tunnel techniques for understanding helped with that development. Another problem that we had, a vibration problem that we had on that engine resulted from a weight saving requirement we had imposed on it. These are things that never get in the press in particular when they are criticizing people for one thing or another, but we had as I recall it a situation where we had this vent where the gases came into the head like this. We had three ducts then, and in order to save weight, we had two. That made an entirely different fluid dynamics situation than this and eventually had to be fixed. That's what happens to you when you design something and then you begin saving weight. Sometimes you forget why you did something in the first place or maybe it's not well enough documented.

Dunar 156: This is what brought on the vibration problem?

Lucas 157: Yes. I think considering the fact that we had the protest and the blackout for a year or plus, the fact that the specifications changed and the fact that we had to undergo a weight saving program on the engine that wasn't yet developed, all of those are complicated problems and must be taken into account when you judge the contract.



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Rocketdyne has always been a very responsive contractor. By that I mean they try to do what you want to have done.

Dunar 158: What about Thiokol?

Lucas 159: The relationship with Thiokol was different in that we considered ourselves expert in what Martin was doing. We considered ourselves expert in what Rocketdyne was doing. We did not consider ourselves expert in what Thiokol was doing. In fact we were not, so we relied heavily on Thiokol heavily to bring the expertise of solid rocket propulsion to the program. We were not able to assess the details of what they were doing. The second thing is that, in defense of Thiokol, we thought they were using state of the art which had been proven over the years, but the problem is that this was the first solid rocket motors launched under a company. You could tell what the situation was. These expendable rockets you launch, we say we bury a lot of problems at sea, you don't know how near the edge you were. I don't know but what the problem that we encountered that resulted in the Challenger accident may have been on the brink of many times in the past. Our relationship with Thiokol was different in that sense.

Dunar 160: I know that the Department of Defense and the Air Force had a lot to do with the configuration of the Shuttle. Were they involved during the development at all?

Lucas 161: They were involved in the inspection yes.

Dunar 162: Inspection during the development of each of the components?

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Lucas 163: Yes.

Dunar 164: How did that relationship work? What authority did their inspectors work in?

Lucas 165: As with any inspector, he has to determine whether the hardware matches the design. That's not unique to this program, but there's this B.C.S.A., the defense systems act or something, where inspection of government hardware is done by an organization of that location. For example, if the Air Force has cognizants over some plants and the Navy has cognizants over some plants. It turns out in all of ours, the Air Force had cognizants over that. We worked with, they called it AFPRO, the Air Force Program Office. That's not a unique up to the shuttle program. It didn't work as well as if you had your own, but that's the way the government had decided to do that.

Dunar 166: It wasn't really intrusive, maybe that's not the right word, but . . . .

Lucas 167: They should have been very intrusive. They should have been out there on the floor making sure that everything is doing exactly like it was designed to do.

Dunar 168: One of the questions that's been raised too is the question of whether all the cutbacks Marshall and the Agency suffered in the early '70s affected the number of inspectors that you had.

Lucas 169: Sure. No question about that.

Dunar 170: How did that influence the development of the shuttle?

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Lucas 171: Well you're comparing what is and what might have been. I would say, I said it at the time and I would say now, if we had of had more inspectors we'd have been more likely to have found the problems that we had and some of the problems that we did find we would have found them earlier. That clearly impacts a program. In this business, a lot of people didn't understand and probably still don't. They talk about low cost ways of doing business. That was the criticism of the Apollo program and now we're going to do it low cost. We've got a new way of doing it. There is only one way of doing a high-risk publicly supported program like this and that's to do it right. To do it right, you've got to have a certain resource of people. You're foolish to cut back. The country ought to decide, well if we can't afford it let's don't do it, but don't do it half-way, and we started to do some things half way in my [?198].

Dunar 172: Inspectors being part of that, were there other things too that you were . . . ?

Lucas 173: Engineering as well. Oversight. I'd count the whole thing oversight - inspection, engineering - the whole thing. I wrote a paper one time that talked about the constants and variables in the management of the Shuttle and the Aapollo program. In the Apollo program, we had some constants and we had some variables. The constant of course was performance. We couldn't compromise on that. We had to go to the moon. It's not going to get, well it might get a little closer but not much. We had a performance. We had a schedule. We had to get there within the decade and then we had cost which was the variable. We were provided the cost that we needed to do the program. In the Shuttle, the thing was entirely different. Cost was a constant. The performance was a constant, and time was the variable. We didn't have any pressure,

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we had pressure of time of course, but we slipped it a lot of times. We didn't have let's do it in this decade kind of thing. I'd say the Shuttle program was strapped from the offset by cost.

Waring 174: Was that paper published or did you present it to a conference?

Lucas 175: I didn't publish it. I was given, it was my own fault, I was given the Roger Jump award by the American University in Washington. As a part of that convocation, I gave this paper. The Dean of the College of Management, I believe that's what they call it there, wanted me to publish it. I said "Well ok." He submitted it to be published, and the reviewers wanted it shortened and a lot of things that I didn't have time to fool with back then.

Waring 176: You didn't need to get tenure!

Lucas 177: That's right, and I'm probably wrong, but I didn't need to get tenure so I said I'll do it for half time, and I never have done it.

Waring 178: If it's possible, Andy and I would both like to read that if you could xerox it [tape ends 254]